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Quantum Cascade Laser Heterodyne Radiometry for Atmospheric Observation

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The composition of the Earth's atmosphere drives climate change. Monitoring the global distribution of atmospheric constituents is highly important both to enable scientists to better understand radiative forcing, chemistry and feedback effects and to inform the decisions of policy makers. The imperative of the scientific drivers places requirements on the next generation of instrumental platforms to be used for measurement of atmospheric composition. High spatial and vertical resolutions are desirable for local monitoring and global sensing at a finer scale, whilst maintaining a high sensitivity and accuracy.

Over the last few years the concept of quantum cascade laser (QCL) spectro-radiometry has been developed in line with these motivations [1, 2]. Presented here is a novel technological step for atmospheric profiling of multiple species using QCL heterodyne sensing. A widely tunable ground-based external cavity quantum cascade laser heterodyne radiometer (EC-QC-LHR) has been designed and built in the laboratory. The prototype instrument is operated in a solar occultation mode with a narrow field of view covering 1/40th of the solar disk, inherent to the high spatial resolution capabilities of the instrument. The EC-QC-LHR is tunable between 1120 and 1238 cm^{-1}. Five pollutants have significant absorption features within this frequency range: ozone, methane, nitrous oxide, dichlorodifluoromethane and water vapor and were therefore investigated.

The capabilities of the instrument were demonstrated in a field campaign conducted during winter 2010-2011 [3]. Spectra were recorded at an ultra high spectral resolution of 60 MHz (0.002 cm^{-1}) covering ten specific $\sim$1 cm^{-1} wide narrow-windows which were selected to study the five absorbing molecules. Analysis to retrieve vertical profiles for the five molecules mentioned was carried out using the optimal estimation method.

As most of the high resolution thermal infrared sounders currently operational are Fourier Transform spectrometers (FTS), a side by side measurement campaign of EC-QC-LHR and FTS (Bruker IFS 125HR) was conducted with high spatial and spectral resolutions for both instruments. Under these conditions, the EC-QC-LHR was found to provide far better signal to noise ratio and temporal resolution than the FTS. The latter has a much wider spectral coverage, however, retrieval analysis showed that with the high spectral resolution of EC-QC-LHR the use of narrow-windows was not detrimental to altitudinal profiling, and demonstrated therefore that wide frequency coverage was not necessary.

All these results will be presented and discussed.

References:

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